UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 926

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 19, 1921

STUDIES IN THE BIOLOGY OF THE MEXICAN COTTON BOLL WEEVIL ON SHORT-STAPLE UPLAND, LONG-STAPLE UPLAND, AND SEA-ISLAND COTTONS.[a]

By George D. Smith, *Entomological Assistant, Southern Field-Crop Insect Investigations.*

CONTENTS.

INTRODUCTION.

The studies in the biology of the Mexican cotton boll weevil (*Anthonomus grandis* Boh.) upon which this paper is based were con-

[a] The cotton varieties used in these studies were a short-staple upland cotton known as King, a long-staple variety known as Webber No. 49, and a sea-island cotton known as Hope Straight.

16073°—21——1

ducted at Madison, Fla., during the years 1918 and 1919. The results recorded herein in addition to representing the first serious study of the boll weevil east of the Mississippi River also indicate the rapidity with which the weevil is adapting itself to new environmental conditions in its spread eastward.

Owing to the very decided effect of climatic factors on the biology of the boll weevil, it has been found necessary to study the development of the weevil under both field and outdoor insectary conditions.

In order to throw some light on the possibility of growing sea-island cotton under weevil conditions, a comparative study of the biology of the weevil on upland, long staple, and sea-island cottons is included herewith. Since all methods of control are usually based upon facts secured from biological studies, the results of the life-history studies recorded herewith are of considerable importance to the cotton growers east of the Mississippi River.

HISTORICAL REVIEW.

A review of the studies in the life history of the boll weevil is presented herewith.[1] This review is of interest in that it shows the times and conditions under which studies have been conducted.

The earliest work was that at Victoria, Tex., in 1902 and 1903, the results being published early in 1904.[2] This was followed by similar investigations at the same place during 1904, and the results of these studies were included in a bulletin issued in 1905.[3]

During 1910 similar investigations were conducted at Tallulah, La., and the results were published in 1911.[4]

Then, in 1912, these studies and such others as had been made elsewhere were brought together in a large bulletin.[5]

During 1913 another series of studies was conducted at Victoria, Tex., to check those which had been made at the same place 10 years earlier. It was found that the weevil had made a number of important changes in its life history, principal among these being a much greater adaptability to plants other than cotton as food. The biology of the Arizona Thurberia weevil was also studied, and this variety was hybridized with the Texas cotton weevils. The results of these studies are included in three papers.[6]

---

[1] Quoted from Howe, R. W., Bul. 358, U. S. Dept. Agr., p. 2–3.

[2] Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 45, 116 p., 16 pl., 6 figs., 1904.

[3] Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. of Agr. Bur. Ent. Bul. 51, 181 p., 23 pl., 8 figs., 1905.

[4] Cushman, R. A. Studies in the biology of the boll weevil in the Mississippi Delta region of Louisiana. *In* Jour. Econ. Ent., v. 4, no. 5, 1911. p. 432–448.

[5] Hunter, W. D., and Pierce, W. D. Mexican Cotton Boll Weevil. U. S. Dept. of Agr. Bur. Ent. Bul. 114, 188 p., 22 pl., 34 figs., 1912.

[6] Coad, B. R., and Pierce, W. D. Studies of the Arizona Thurberia weevil on cotton in Texas. Proc. Wash. Ent. Soc., v. 16, no. 1. p. 23–28. 1914.

Coad, B. R. Feeding habits of the boll weevil on plants other than cotton. U. S. Dept. Agr. Jour. Agr. Res., v. 2, no. 3, p. 235–245. 1914.

Coad, B. R. Recent studies of the Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bul. 231, 34 p., 1 fig. 1915.

In 1914 the life history and habits of the Arizona weevil were studied under natural conditions in the mountains near Tucson, Ariz. These studies are discussed in two papers.[7]

Thus it is seen that these studies embrace a wide range of time and conditions. In fact, the conditions of humidity, rainfall, temperature, altitude, soil, etc., include practically all extremes found in the cotton belt.

SCOPE OF THE PRESENT LIFE-HISTORY STUDIES.

The biological studies of the boll weevil at Madison, Fla., during the year 1918, included a thorough study of the boll weevil under outdoor insectary conditions on both upland and sea-island cottons. The main object of this study was to determine the difference, if any, in the weevil's biology on the two kinds of cotton. During the month of August, 1918, a small series of experiments was made to determine the length of the developmental period of the weevil from egg to adult under actual field conditions. The results of the field studies indicated conclusively that a wide variation existed in the length of time required for the developmental period of the weevil under insectary conditions compared with the true developmental period under normal field conditions. Consequently the studies in the biology of the weevil during the year 1919 were arranged to include a thorough study of the field biology of the boll weevil. Insectary studies in the biology of the weevil were conducted at the same time the field tests were under observation, to serve as a check.

METHODS USED IN THE STUDY OF THE BOLL WEEVIL UNDER OUTDOOR INSECTARY CONDITIONS.

The numerous experiments of 1918 were conducted in a specially constructed outdoor insectary at the Madison, Fla., laboratory (fig. 8). The sides of the insectary building were constructed entirely of 16-mesh galvanized wire screen from the floor to the ceiling, which permitted free air circulation at all times. The roof of the insectary building extended 2 feet over the sides of the building, preventing the direct rays of the sun from touching any of the breeding jars. All the insectary breeding work was conducted in glass tumblers half filled with white sand. The sand was kept constantly moist. Lantern globes with cheesecloth covers were used for the longevity experiments.

---

[7] Coad, B. R. Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. U. S. Dept. Agr. Bul. 233, 12 p., 4 pl. 1915.

Coad, B. R. Studies on the Biology of the Arizona Wild Cotton Weevil. U. S. Dept. Agr. Bul. 344, 23 p., 2 pl., 1 fig. 1916.

METHODS USED IN THE STUDY OF THE BIOLOGY OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

Large 16-mesh galvanized-wire screen cages 3 by 3 by 4 feet high were used in conducting the field biological studies of the weevil. The cotton plants used in the breeding work were first examined carefully to make certain that no infested squares were present. The large cages were then placed over the plants and a male and a

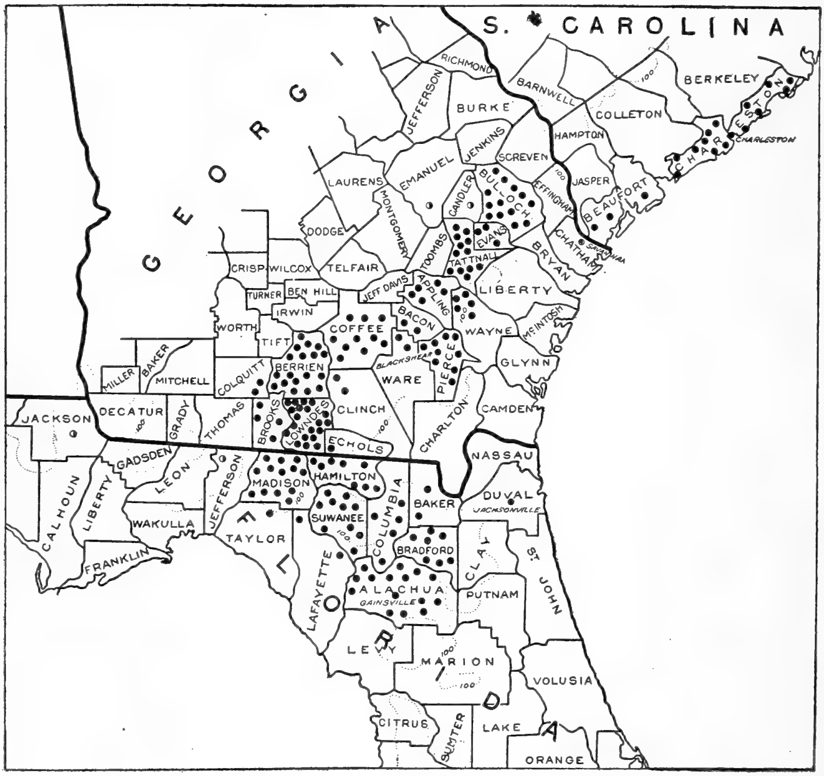

FIG. 1.—Map of the sea-island cotton area of the United States showing distribution by counties. Each dot represents an average production of 500 bales. (From Orton, Bur. Plant Industry, U. S. D. A.)

female boll weevil liberated in each cage. On the following day all squares found with egg punctures were recorded, each infested square bearing a light string tag showing the number of the weevil and the date of the egg puncture. After the squares were examined and tagged the cage and weevil were removed to a noninfested plant and the process repeated. Daily observations were made on the plants bearing the tagged squares and the date the infested square dropped off the plant was recorded on the tag. As soon as the infested squares dropped off the plants they were placed in a field hatchery

(fig. 7). The field hatchery consisted merely of a certain area in the cotton field about 20 feet square. The infested squares were placed in the hatchery beneath the cotton plants in the natural position of fallen squares. After 15 days from the date of egg puncture the infested squares were placed in small wire-screen hatching cages (fig. 7). The hatching cages were constructed of 16-mesh wire without bottoms and protected the infested squares in such a manner that the squares received about the same amount of sunshine and moisture as under normal field conditions. Maximum and minimum thermometers were installed in the field hatchery (fig. 9). Both instruments were resting on the soil in order that the exact minimum and maximum temperatures to which the developing weevil was subjected under field conditions might be determined.

Ten hibernated male and female weevils were used to secure the developmental period of the first generation of weevils on upland cotton. In addition, 10 hibernated female weevils that had not been fertilized were used to determine the effect of nonfertilization after emergence from hibernation on the progeny produced. When the first generation weevils became adults 10 pairs were selected and used for securing the fecundity records on upland, long staple, and sea-island cottons. The fecundity records for the second generation on upland cotton were secured in a like manner. After the 15th of August, however, the weevils had developed so rapidly in the field that it was necessary to discontinue the study of the developmental period of the weevil for each successive generation.

For securing the effect of the lower fall temperatures on the developmental period of the weevil, upland cotton plants were stripped of all cotton squares and then caged. As soon as the plants grew new squares female weevils were placed in the cages for oviposition purposes. About every 20 days a new series of developmental studies was inaugurated. This process was continued until frost killed the cotton plants in late fall.

FOOD PLANTS OF THE BOLL WEEVIL.

Owing to the economic importance of the question as to whether or not the boll weevil can adapt itself to plants other than cotton for food, this phase of the life history has been carefully studied in practically every section of the cotton belt.

The boll weevil has as regular food plants the cultivated cottons of the United States, Mexico, Cuba, and Central America, and certain wild cottons, including *Gossypium davidsoni* on the coast of the Gulf of California, and also the so-called wild cotton, *Thurberia thespesioides*, in Mexico and Arizona.

The breeding experiments of Coad and Howe, both published, show that the weevil can live on Hibiscus, and Coad reared an adult from Hibiscus, but the weevil can not normally attack the plant. So far as we know, there are no plants growing in Florida or the southern States that are adapted to serve as food plants of the boll weevil.

THE BOLL WEEVIL ON SEA-ISLAND COTTON.

FEEDING EXPERIMENTS TO DETERMINE THE PREFERENCE SHOWN BY THE BOLL WEEVIL FOR SEA-ISLAND COTTON.

A known number of adult boll weevils were placed in battery jars and allowed to feed on bolls, squares, and leaves. Each jar contained both sea-island and upland bolls, squares, and leaves, and careful records were taken every two hours to determine whether there was any preference by the weevil for either of the two types of cotton fruit and foliage. The experiments were conducted in an outdoor insectary where normal atmospheric conditions prevailed. The data obtained in order to ascertain whether there is any preference by the boll weevil for sea-island as compared with upland cotton are given in Table I. The records presented in this table show that the boll weevil seems to prefer sea-island foliage to upland foliage, and that it shows a distinct preference for sea-island bolls compared with upland bolls. It appears also that there is a tendency to feed on upland squares in preference to sea-island squares.

TABLE I.—*Feeding choice of boll weevil between sea-island and upland cotton, Madison, Fla.*

Food.	Number weevils used in experiment.	Total number individual observations.	Total number of times weevils were observed.			Percentage of feedings recorded on—	
			Feeding on upland cotton.	Feeding on sea-island cotton.	Resting on cage.	Upland cotton.	Sea-island cotton.
Bolls	10	290	64	118	108	22.0	40.6
Squares	10	290	135	110	44	46.9	37.9
Leaves	10	290	77	129	84	26.5	44.4
Total	30	870	276	357	236	[1] 31.8	[1] 40.9

[1] Average.

In Table I attention is called to the preference by the boll weevil for sea-island bolls over upland bolls in the experiments conducted on the feeding habits of the weevil. In 1917, in order to secure further data on this phase of the weevil's attack, the writer examined at random each week 100 grown bolls of each variety of upland and sea-island cottons that were still green, beginning on the 19th of July, the

bolls being collected under similar field conditions. These records were continued throughout August and to the 1st of September. Table II shows the results of this examination:

TABLE II.—*Record of weevil infestation in green bolls of sea-island and upland cottons, Madison, Fla.*

Date of examination.	Total number bolls examined.	Upland cotton bolls.		Sea-island cotton bolls.	
		Number clean.	Number punctured.	Number clean.	Number punctured.
1917.					
July 19	200	91	9	74	26
July 26	200	89	11	81	19
Aug. 4	200	92	8	69	31
Aug. 11	200	92	8	69	31
Aug. 20	200	91	9	61	39
Aug. 25	[1] 600	36	64	[2] 166	[3] 334
Sept. 1	200	38	62	29	71
Total	1,800	529	171	549	551
Per cent punctured			24.4		50.09

[1] 500 sea-island. [2] 33 per hundred. [3] 67 per hundred.

A careful study of Table II shows that the number of weevils attacking sea-island bolls was far greater than the number attacking upland bolls. Observations in the field also show that a great many more weevils are to be found feeding on the sea-island bolls than on upland cotton bolls.

LONGEVITY OF ADULT BOLL WEEVILS ON UPLAND AND SEA-ISLAND COTTON.

The length of time adult weevils live on upland cotton has been determined for several different times and places. The object of the longevity tests at Madison, Fla., was to determine whether there was any considerable difference in the length of life of weevils fed on upland and sea-island cottons.

Table III gives the observations on the longevity of the weevil when fed upon different parts of the upland cotton plant. The maximum longevity of 84 days was shown by a male weevil that had hibernated over the preceding winter and emerged from hibernation during the month of April. The average longevity for hibernated weevils without food was 12.7 days, compared with an average of 18.8 days for hibernated weevils fed on cotton plantlets. Adult weevils of the first and second generations lived an average of 24.3 days on cotton squares and 12.3 days on green cotton bolls.

Table IV gives the data concerning the longevity of boll weevils on sea-island cotton. The maximum longevity on sea-island cotton

TABLE III.—*Longevity record of boll weevils, summary of the observations at Madison, Fla., 1918.*

Date.	Kind of food.	Males.				Females.				Both sexes.		
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	Source of weevils.
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
Feb. 22 to 28	No food	56	589	13.3	33	33	402	12.1	34	34	12.7	Hibernated.
Mar. 1 to 31	do	48	712	14.8	40	49	900	18.3	53	53	16.5	Do.
Apr. 1 to 30	do	26	365	14.03	27	27	352	13.03	34	34	13.5	Do.
May 1 to 31	do	23	198	8.6	15	12	100	8.3	14	15	8.4	Do.
June 1 to 30	do	1	27	2.7	27							Do.
Total		154	1,891			121	1,754					
Average				10.68				12.93			12.7	Do.
Maximum					40				53	53		
Mar. 1 to 21	Upland plantlets	25	596	23.8	81	35	711	20.3	76	81	22.0	Do.
Apr. 1 to 30	do	17	376	22.1	84	21	412	19.6	34	84	20.8	Do.
May 1 to 31	do	24	358	14.8	39	5	61	12.5	27	39	13.6	Do.
Total		66	1,330			61	1,184					
Average				20.2				17.4			18.8	Do.
Maximum					84				76	84		
June 26 to 30	Upland squares	127	2,680	21.1	74	52	1,139	21.9	70	74	21.5	First generation.
July 20 to 21	do	20	412	20.6	38	17	407	23.9	50	50	21.5	Second generation.
Total		147	3,092			69	1,546					
Average				20.8				22.9			24.3	
Maximum					74				70	74		
July 6 to 8	Upland bolls	34	543	15.9	49	36	472	13.1	47	49	14.5	First generation.
July 24 to 31	do	19	161	8.4	19	2	24	12	12	19	10.2	Second generation.
Total		53	704			38	496					
Average				12.1				12.5			12.3	
Maximum					49				47	49		
Total upland cotton		420	7,017	15.94		289	4,980	16.43	76	84	17	

TABLE IV.—*Longevity of the boll weevil on sea-island cotton, Madison, Fla., 1918.*

Date.	Kind of food.	Males.				Females.				Both sexes.		
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	Source of weevils.
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
Apr. 1 to 30	Sea-island plantlets	3	27	9	11	3	37	12. 3	13	13	10. 6	Hibernated.
May 1 to 31	do	22	268	12. 2	35	7	76	10. 9	23	35	11. 5	Do.
Total		25	295			10	113					Do.
Average				10. 6				11. 6			11. 05	
Maximum					35				23	35		
June to July	Sea-island squares	91	1, 730	19. 01	65	81	1, 690	20. 4	67	67	19. 7	First generation.
July 6 to 25	do	23	196	8. 4	18	6	44	7. 3	13	18	1. 8	Second generation.
Total		114	1, 926			87	1, 734					
Average				13. 7				13. 8			10. 7	
Maximum					65				67	67		
July 6 to 9	Sea-island bolls	32	539	16. 5	52	62	1, 203	19. 4	43	52	17. 9	First generation.
July 24 to 28	do	20	201	10. 05	17	8	124	15. 5	33	33	12. 7	Do.
Total		52	740	13. 2		70	1, 327	17. 4				
Total sea-island cotton		191	2, 961			167	3, 174					
Average				12. 5				14. 2			12. 3	
Maximum					65				67	67		

was made by a first-generation female weevil that became adult during the latter part of June. This weevil lived a total of 67 days. The maximum length of life for the male weevils was also recorded for a first-generation weevil that became adult during the latter part of June. This weevil lived a total of 65 days. The average longevity for hibernated weevils fed with sea-island cotton plantlets was 11.05 days. The weevils lived 10.7 days on sea-island squares and 15.3 days on green sea-island cotton bolls. By comparing the average longevity of the weevil on sea-island cotton with the average longevity on upland cotton, it is clearly demonstrated that there is little, if any, difference in the food value of sea-island and upland cotton on the longevity of adult weevils.

THE SIZE OF THE COTTON SQUARE ATTACKED BY BOLL WEEVILS.

Male and female weevils feed largely on the cotton squares, except in the case of sea-island cotton, where there is a decided tendency to feed upon the bolls as well as the squares. Upland cotton squares grow very rapidly and there is little opportunity afforded for direct feeding on the very small squares, except during the period when the first squares come on the plants and again when all squares are punctured. However, sea-island squares do not grow very rapidly and a large number of the small squares are shed by the plant from feeding and egg punctures.

FIG. 2.—Three sizes of sea-island cotton squares chosen for oviposition by the boll weevil.

It has been observed that a large number of undersized weevils are produced in sea-island cotton fields. These weevils are largely the result of eggs having been deposited in undersized squares, which resulted in an undersized weevil, owing to the lack of proper larval food (fig. 2). When a large number of sea-island squares are offered a female it has been observed that she invariably chooses the smaller squares for oviposition purposes. No records are available to show the length of the developmental period for weevils developing in undersized squares on sea-island cotton; however, it is not thought that there is much variation from that in large-sized squares. Observations on the size of weevils bred from bolls show that, except in the case of very young bolls which shrivel and dry very rapidly, nearly all weevils produced are of normal size. Sea-island cotton bolls seldom produce small-sized weevils, as the boll is very moist and furnishes much better conditions for weevil development than upland cotton bolls.

LOCATIONS SELECTED FOR OVIPOSITION ON SEA-ISLAND AND UPLAND COTTON SQUARES.

Upland cotton squares are usually punctured at the base of the square, as is shown in Plate I, figure 2. During the writer's studies at Thomasville, Ga., in 1916, the majority of the punctures were observed, in the case of sea-island cotton, to be on the upper portion of the square. There is little proliferation around the weevil punctures on the sea-island squares, the punctures being mere specks as compared to those on upland cotton. This characteristic location for egg deposition is shown in Plate I, figure 1.

PERIOD FROM EMERGENCE TO OVIPOSITION.

Female weevils bred in the outdoor insectary required an average period of 8.9 days from the time they became adult to the date of oviposition. The period of time from emergence to oviposition varied from 6 to 20 days for weevils bred under insectary conditions.

Boll weevils bred under normal field conditions appeared to have more vitality than weevils bred under insectary conditions. A record of 38 first-generation weevils bred under normal field conditions gave an average period of 7.07 days from the time they became adult to the date of oviposition.

OVIPOSITION PERIOD OF THE BOLL WEEVIL UNDER INSECTARY CONDITIONS.

The oviposition records for the weevil on upland cotton are presented in Table V. Hibernated female weevils kept with male weevils throughout life deposited eggs over an average period of 35.9 days compared with an average period of 21.7 days for females that were not kept with male weevils. The hibernated fertilized and nonfertilized weevils deposited a total of 3,605 eggs or an average of 7.2 eggs per day per female. During the lifetime of both series of hibernated weevils an average of 171 eggs was deposited by each female. The greatest number of eggs deposited during any one day by a single hibernated female weevil, under insectary conditions, was 20. The heaviest oviposition during the lifetime of both series of weevils was from the fifth to twenty-fifth days (fig. 4). The first-generation weevils deposited eggs for a period of 39.7 days and the second generation over a period of 35.2 days. The average period of oviposition on upland cotton for all weevils under observation was 33.1 days. The relationship between the mean daily temperature and the mean daily oviposition of the hibernated weevils is shown to cor-

respond very closely; that is, the higher the mean daily temperature the higher the average number of eggs until the period of oviposition begins to decline (fig. 3).

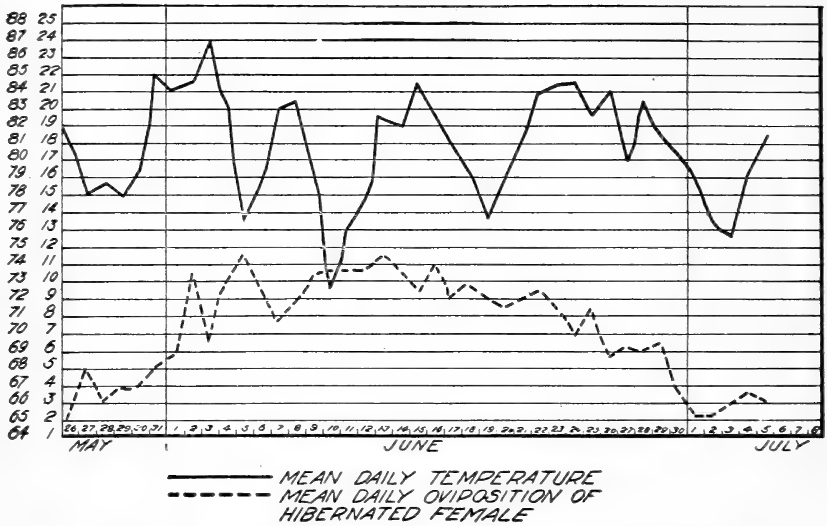

FIG. 3.—Relation of mean daily temperature to mean daily oviposition of hibernated weevils.

The oviposition records of the boll weevil on sea-island cotton differ very little from those on upland cotton under insectary conditions. The female weevils fertilized in the spring deposited eggs for an average period of 31 days and the hibernated weevils

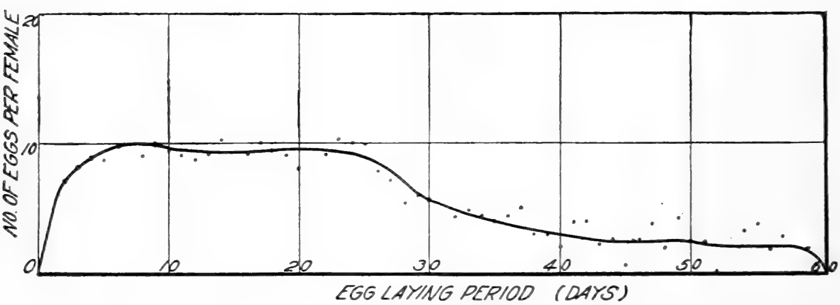

FIG. 4.—Mean daily oviposition of female weevils in upland cotton squares.

fertilized in the fall, for an average period of 27.1 days. The first and second generation weevils deposited eggs for average periods of 35.4 and 33.6 days, respectively. The average oviposition period for the females in sea-island cotton squares is shown to be 31.6 days.

TABLE V.—*Oviposition period of the boll weevil on upland and sea-island cotton squares, insectary records, Madison, Fla., 1918.*

Source of weevils.	Season.	Number of females.	Upland cotton—period.			Number of females.	Sea-island cotton.		
			Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.
			Days.	*Days.*	*Days.*		*Days.*	*Days.*	*Days.*
Hibernated	May-July	12	59	16	35.9	15	52	18	31
Hibernated, fall fertilization.	do	10	53	5	21.7	10	44	16	27.1
First generation	June-August	8	55	31	39.7	10	47	25	35.4
Second generation	July-September.	10	45	20	35.2	10	46	19	33.6
Total		40			33.1	45			31.6

SUMMARY OF THE FECUNDITY OF THE BOLL WEEVIL ON SEA-ISLAND AND UPLAND COTTONS UNDER INSECTARY CONDITIONS.

Table VI gives a summary of the fecundity records of the boll weevil on sea-island and upland cottons. Here it is shown that the average number of eggs per day was highest with hibernated weevils for both types of cotton. The maximum number of eggs per day was made by a first-generation female on upland cotton and the maximum number per day on sea-island cotton was made by a hibernated weevil. The average number of eggs per female on upland cotton was 166.1 and the average number of eggs per day 4.92. On sea-island cotton the average number of eggs per female fell to 113.5 and the average per day to 3.8. These averages compare closely with those secured on upland cotton at Victoria, Tex., in 1913, where the females deposited an average of 212 eggs each and oviposition was at a rate of 5.9 eggs per day.

TABLE VI.—*Summary of the fecundity of boll weevils on sea-island and upland cottons under insectary conditions, 1918.*

Source.	Number of females.	Average number of eggs per female.	Average oviposition period.	Eggs per day.	
				Average.	Maximum.
Upland cotton:			*Days.*		
Hibernated	12	270.3	35.9	7.18	20
Hibernated, fall fertilization	10	117.7	21.7	5.4	19
First generation	8	222.8	39.7	5.6	25
Second generation	10	53.9	35.2	1.5	7
Total	40				
Average		166.1	33.1	4.92	
Sea-island cotton:					
Hibernated	15	214.7	31	7.38	19
Hibernated, fall fertilization	10	122	27.1	4.5	16
First generation	10	79.9	35.4	2.2	11
Second generation	10	37.5	33.6	1.11	7
Total	45				
Average		113.5	31.7	3.8	

THE AVERAGE DEVELOPMENTAL PERIOD OF THE COTTON BOLL WEEVIL UNDER OUTDOOR INSECTARY CONDITIONS.

The data on the average developmental period of the boll weevil under outdoor insectary conditions for sea-island and upland cottons are presented in Table VII. These observations extended over a period of time beginning on May 26 and ending on September 10. The maximum developmental period of any weevil from egg to adult was 18 days and the minimum period 11 days. On upland cotton 506 male weevils bred in the insectary required a total of 7,568 weevil days, or an average period from egg to adult of 14.62 days. A total of 347 female weevils bred under insectary conditions required an average developmental period of 14.8 days. The average period of development for the immature stages bred in upland cotton squares is shown to be 14.91 days.

On sea-island cotton 150 male weevils required 2,214 weevil days from egg to adult, or an average developmental period of 14.82 days. A total of 101 female weevils, bred in sea-island cotton squares, re-required 1,550 weevil days, with an average period of 15.06 days for development from egg to adult. There is practically no difference in the time required for development of the immature stages of the boll weevil in sea-island and upland cotton squares.

TABLE VII.—*Total developmental period of the boll weevil under insectary conditions, Madison, Fla., 1918.*

Source of weevils.	Larval food.	Oviposition period.	Males.			Females.			Both sexes.		
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.	Total number bred.	Total weevil days.	Average developmental period.
Upland cotton:					*Days.*			*Days*			*Days.*
Hibernated	Cotton square.	May 26–July 27	201	2,931	14.09	126	1,812	14.38	327	4,726	14.4
Do	...do	May 29–July 23	57	816	13.4	41	564	13.7	98	1,380	14.08
First generation.	...do	June 14–Aug. 15	208	3,183	15.3	133	2,029	15.2	341	5,218	15.38
Second generation.	...do	July 17–Sept 5.	40	638	15.7	47	742	15.9	87	1,380	15.8
Total			506	7,568	......	347	5,147	......	853	12,704	......
Average			......	......	14.62	......	......	14.8	......	......	14.91
Sea-island cotton:											
Hibernated	Cotton square.	May 26–July 20	67	965	13.5	46	689	13.46	115	1,654	14.3
Do	...do	May 25–July 18	34	490	14.4	15	220	14.6	49	690	14.08
First generation.	...do	June 21–Aug. 15	33	498	15.09	15	249	16.6	48	746	15.5
Second generation.	...do	July 11–Sept. 4	16	261	16.3	25	392	15.6	41	653	15.9
Total			150	2,214	......	101	1,550	......	253	3,743	......
Average			......	......	14.82	......	......	15.06	......	......	14.94

THE DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

Although it has been known that the factors of temperature and humidity influence the development of the boll weevil, and that laboratory breeding methods are more or less artificial, the exact difference between the life history of the weevil under field conditions and in the laboratory has never been determined.

In the experimental work at Madison, Fla., in 1918, it was found that the boll weevil in the field was requiring a considerably longer period for development than had been expected. Records tabulated by Hunter and Pierce[8] showed that the length of the developmental

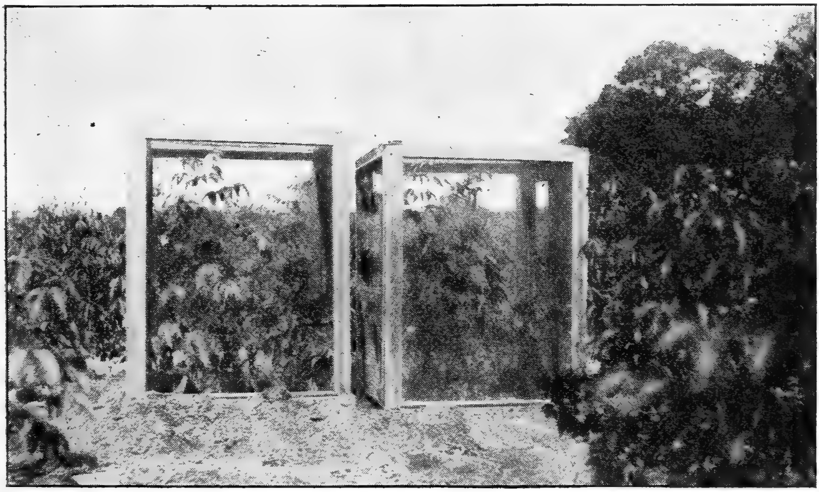

FIG. 5.—Cages used in the oviposition studies of the boll weevil under field conditions, Madison, Fla.

period varied with the length of time the infested squares hung on the plant after egg puncture. The Madison studies fully corroborate this statement.

The field-breeding records were secured under conditions which most nearly simulate nature. A large cage was placed over a cotton plant on which there were no infested squares (fig. 5). A single female or a male and female were liberated in the cage with the non-infested squares. On the second day if any squares were infested these were tagged (fig. 6) and the cage and weevil were then removed to a fresh cotton plant from which all infested squares had been removed. Thus day by day the weevil's maximum oviposition capacity was obtained and the infested squares remained on the plant

[8] Hunter, W. D., and Pierce, W. D. The Mexican Cotton Boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911. Senate Document 305 (U. S. Dept. Agr., Bur. Ent. Bul. 114). 188 p., 22 pl., 33 figs. 1912.

normally, merely being weighted by a light string tag. When the infested squares fell the date was recorded on the tag. All of the infested squares of a certain weevil were assembled in an inclosed area to prevent damage (fig. 7) and placed on the soil under the plant just as they would normally lie. They were watched daily, and only about two days before emergence was expected were covered, still under the plant, by coarse wire screen cages (fig. 7) in order to get the number of weevils that emerged and determine the sex. Hence abnormal conditions were experienced for only about 2 days.

FIG. 6.—The infested squares tagged on the cotton plant, Madison, Fla.

Since these records indicated a much longer developmental period than was recorded in previous bulletins, a complete series of control experiments was conducted in the outdoor insectary (fig. 8).

It will be seen by Table VIII that the developmental period in the tumblers under insectary conditions at Madison is much more rapid than under the most favorable outdoor conditions experienced.

TABLE VIII.—*Showing the length of the developmental period of the boll weevil under insectary and field conditions, Madison, Fla., 1918.*

Ten-day oviposition period.	In insectary, developmental period.				Outdoors, normal developmental period.				Average.
	Number of weevils bred.	Days.			Number of weevils bred.	Days.			Acceleration of insectary days.
		Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.	
June 4-13	370	15.6	13.6	14.8	50	24.5	20.1	21.6	6.8
July 3-13	306	15.2	13.7	14.5	94	24.2	20.8	21.9	7.4
July 31-Aug. 9	87	18	14.8	15.8	54	24.3	19.6	23.2	7.4

The development of the weevil is retarded on the plant, and more so on the ground, and accelerated in the insectary. The outside soil is either too hot or too cool and damp, while the insectary maintains a more even condition, warmer than the plant and cooler than the ground.

If one feels of a leaf or square on a hot day he immediately receives a sensation of coolness. If he lays his hand on the sand in the shade of the plant it feels cool and damp, and if he lays the other hand on the sun-heated sand he experiences a sensation of burning.

Dr. Pierce made a series of temperature measurements on June 21, 1919, in a period of less than 2 hours (from 10 to 12 "daylight-saving

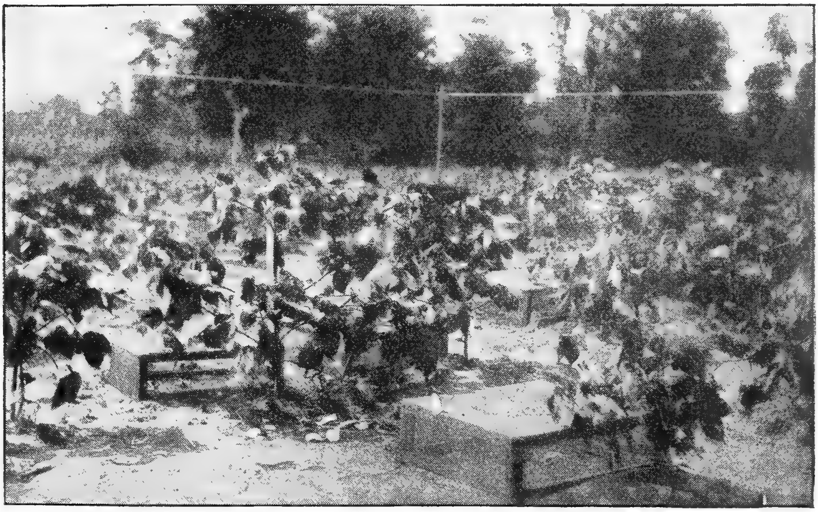

FIG. 7.—The field hatchery, Madison, Fla.

time," or 9 to 11 astronomical time) in which the air temperature about 2 feet above the ground was 88.5° to 89.5° F.

The humidity by sling psychrometer was 68.5 to 69 per cent, by wet bulb 73.5.

The temperature of the sandy soil in the sun was 106.5°, 111°, 111°, and 115° F. at different readings. Once in a while clouds shaded the earth.

In the shade of the cotton plants the temperature of the sandy soil was 92.7°, 93°, and 94° F. at different readings; in other words, the shade of the cotton plant reduced the temperature 14°, but the air temperature was 4° or 5° cooler than the sand under the plant.

Behind the involucre of the square on the plant the temperature was 88° F., and next to the stem of the plant, 2 feet above the ground, it was the same.

When the thermometer was wrapped in cool, green leaves it registered 89° F., but when inserted into a square and wrapped in green leaves it registered 81°.

The thermometer covered one-fourth inch by hot sand in the sun registered 106.5° to 107.5° F.; under one-half inch of sand it registered 99°, under 1 inch 95°, and under 1½ inches of sand 91°.

Thus shallow burial of infested squares would merely give the immature weevils more favorable temperatures and almost insure emergence; while the sun-heated surface soil, even on this moderate day, was heated very close to a fatal temperature.

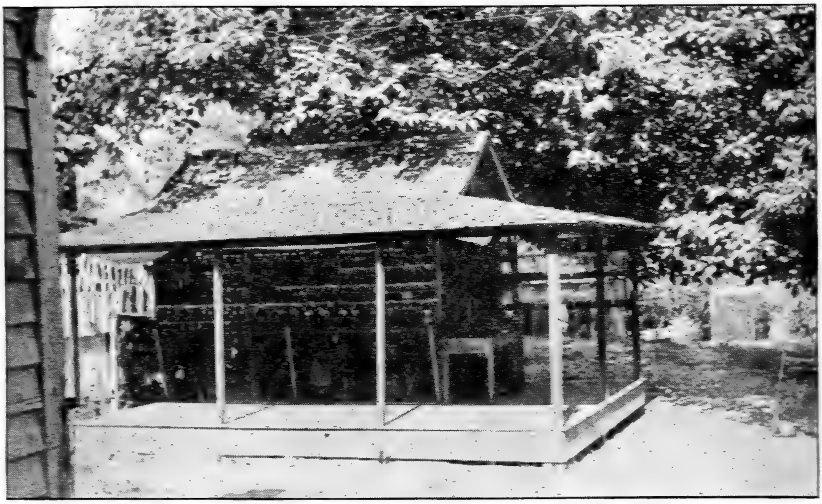

FIG. 8.—Outdoor insectary, Madison, Fla., where the records were secured to check against the field records.

Dr. Pierce then studied the temperature in the field breeding cages and found in the oviposition cage an air temperature of 85° F., a soil temperature in the sun of 108° to 108.5°, in the shade of the wire screen 90° to 94.5°, and in the shade of the plant 92° to 95°. The humidity in the cage was 71.5 per cent, wet bulb 85, while in the open air it was 68.5 per cent, wet bulb 85.5. There is therefore very little difference in the temperature in and out of the cage.

The small wire-screen cages used to cover the squares during the last two days before emergence were then measured. In the shade of the plant the temperature was 94.5° to 96.5° F. and in the sun 103° to 106°. The cage, therefore, serves to mitigate slightly the intense heat.

In the insectary measurements were made in the breeding tumblers. A temperature of 83.5° F. was recorded for the soil in the tumblers, while above the soil the temperature was 86.5° F. Since the tumblers were only moistened once during the hatching period, a temperature

reading on the seventh day gave 84° on the soil and 87° above the soil in the tumblers. On the twelfth day the temperature was 84° on the soil and 86.5° above the soil. Thus, on this particular day, weevils developing in squares on the plant were experiencing 88° F., or probably less, and those in the squares which had fallen on the ground were receiving from 92° to 115° F., according to whether they were shaded or exposed to the sun, while weevils in the insectary were faring well at 83.5° to 87° F. It has been shown that the most favorable temperature for development is between 83° and 84° F.

FIG. 9.—Thermometers installed underneath the cotton plants in the field to secure soil temperature, Madison, Fla.

In order completely to check up conditions maximum and minimum thermometers were installed in the field hatchery. Thus the maximum and minimum temperatures experienced by the weevils after the falling of the infested square (fig. 9) were measured.

EGG-LAYING ACTIVITY OF HIBERNATED FEMALE WEEVILS UNDER FIELD CONDITIONS.

Table IX gives the data on the egg-laying activities of female weevils under field conditions on upland cotton squares. The females deposited an average of 76 eggs each at a rate of 8.4 eggs per day. The maximum number of eggs during any one day was 19. It is practically impossible to keep a continuous record of female weevils

under field conditions. Female weevils liberated in large cages over growing cotton plants frequently get killed accidentally, spiders sometimes catch them, and they escape very readily from the cages. The records presented in Table XI really indicate the rate of oviposition per day instead of the average number of eggs deposited per female.

TABLE IX.—*Egg-laying activity of individual hibernated female boll weevils kept with males under field conditions on upland cotton.*

Parent weevil.		Date of first egg.	Date of last egg.	Total number of eggs deposited.	Average number of eggs per day.	Maximum number of eggs per day.	Source of weevils.
Generation.	No.						
Hibernated	A 1	May 29	June 1	28	7	8	Hibernated field collected.
Do	A 2	...do	June 21	218	9.9	19	Do.
Do	A 3	May 31	June 5	33	5.5	7	Do.
Do	A 4	June 1	June 14	80	6.1	9	Do.
Do	A 5	...do	June 8	65	9.3	18	Do.
Do	A 7	June 8	June 15	63	7.9	13	Do.
Do	A 8	June 9	June 13	49	9.8	13	Do.
Do	A 9	June 8	June 14	68	9.7	14	Do.
Do	A 10	...do	June 19	70	5.8	11	Do.
Do	A 13	June 12	June 21	88	11	19	Do.
Do	A 14	...do	June 23	97	8.1	19	Do.
Do	A 16	June 18	June 22	54	10.8	18	Do.
Total				913		168	
Average				76	8.4		
Maximum				218	11	19	
Minimum				33	5.5		

LENGTH OF TIME UPLAND COTTON SQUARES HANG ON THE PLANTS AFTER EGG PUNCTURE.

In Table X are found the data on the length of time squares hang on the plants after egg puncture by the weevil. The average number of days from the time the egg is deposited until it drops off the plant is shown to be 11.5 days. The maximum length of time any square hung on the plant after egg puncture was 19 days and the minimum period 6 days.

The length of time elapsing from the date of falling of the infested square from the cotton plant to the emergence of the adult weevil is shown to be 10.8 days. Practically one-half of the weevil's immature stage is developed while the square is on the plant. The minimum number of days from falling of the infested square to the emergence of the adult weevil was 3 days and the maximum number 19 days.

TABLE X.—*Showing development of weevil as related to the length of time squares hung on plants after egg puncture, eggs deposited by hibernated females on upland cotton.*

Date oviposition began.	Total number squares under observation.	Total number days on plant after puncture.	Minimum number days on plant after puncture.	Maximum number days on plant after puncture.	Average number days from puncture to falling of square.	Total number squares under observation.	Total number days from falling to adult.	Minimum number days from falling to adult.	Maximum number days from falling to adult.	Average number days from falling of square to adult.
May 29	29	315	7	15	11.6	12	122	7	12	10.1
May 27	100	1,125	6	18	11.2	17	185	7	15	10.8
May 31	24	269	8	16	11.2	9	82	7	11	9.1
June 1	33	400	6	17	12.1	11	108	3	13	9.8
Do	24	307	10	19	12.7	2	21	10	11	10.5
June 8	23	265	7	17	10.6	7	79	7	16	11.2
June 9	12	148	6	15	12.3	2	22	10	12	11
June 8	42	482	7	19	11.4	9	105	9	16	11.6
Do	51	514	7	13	10.7	8	107	10	16	13.3
June 12	28	289	6	16	10.3	14	156	9	19	11.1
Do	36	410	6	16	11.3	7	83	10	15	11.8
June 18	19	240	9	19	13.6	4	39	9	11	9.7
Total	421	4,764	85	200		102	1,109	98	167	
Average			7.08	16.6	11.5	8.5		8.1	13.9	10.8
Maximum			10	19	13.6	17		10	19	13.3
Minimum			6	13	10.3	4		3	11	9.1

FECUNDITY RECORDS OF HIBERNATED FEMALE BOLL WEEVILS ON UPLAND COTTON UNDER FIELD CONDITIONS.

The data on the fecundity of hibernated female weevils under field conditions are presented in Table XI. Of the progeny produced by the individual female weevils 73 males required 1,536 weevil days, or an average period of 21.7 days, for development from egg to adult. A total of 52 female weevils required 1,145 weevil days, or an average period of 20.2 days, for development of the immature stage. The average period of development for both sexes under actual field conditions was 21.7 days, with a maximum of 24 and a minimum of 19.5 days for the first-generation weevils. A total of 17.99 per cent of the infested squares produced adult weevils. This percentage is remarkably low compared with the generally accepted belief that approximately 35 per cent of the infested squares produced adults. At Madison the Norfolk sandy soil is so well drained that the developing weevils are exposed to terrific heat during the time the square is on the soil before the adult weevils emerge. Consequently a very large mortality occurs among the immature stages of the weevil.

TABLE XI.—*Fecundity record of individual hibernated females of the boll weevil fertilized in spring under field conditions on upland cotton.*

Date oviposition began.	Number eggs deposited normally.	Progeny produced by individual females. Males. Weevils bred.	Males. Weevil days.	Males. Developmental period.	Females. Weevils bred.	Females. Weevil days.	Females. Developmental period.	Both sexes. Total weevils bred.	Both sexes. Total weevil days.	Both sexes. Period both sexes.	Percentage punctured squares producing adults.
				Days.			*Days.*			*Days.*	
May 29	28	10	188	20.8	6	124	20.6	16	312	19.5	57.1
Do	218	15	297	21.2	7	148	21.1	22	445	20.2	10.08
May 31	33	7	137	19.6	3	60	20	10	197	19.7	30.3
June 1	80	4	93	23.2	7	166	23.3	11	259	23.5	13.7
Do	65	2	43	21.5	0	0	0	2	43	21.5	13.07
June 8	63	6	132	22	4	92	23	10	224	22.4	15.8
June 9	49	1	22	22	1	23	23	2	45	22.5	4.08
June 8	68	7	170	24.2	3	70	23.3	10	240	24	14.7
Do	70	6	125	20.8	7	152	21.7	13	277	21.3	18.5
June 12	88	5	120	24	3	67	22.3	8	187	23.3	11.4
Do	97	5	104	20.8	7	152	21.7	12	256	21.3	13.6
June 18	54	5	105	21	4	91	22.7	9	196	21.7	13.6
Total	913	73	1,536	....	52	1,145	....	125	2,681	....	....
Average	76.08	....	....	21.7	....	....	20.2	....	....	21.7	17.99
Maximum	218	15	....	24.2	7	....	23.3	22	....	24	57.1
Minimum	28	1	....	19.6	0	....	0	2	....	19.5	4.08

SUMMARY OF THE DEVELOPMENTAL PERIOD OF THE FIRST-GENERATION BOLL WEEVILS IN UPLAND COTTON SQUARES UNDER FIELD CONDITIONS.

Table XII gives a summary of the period of development in upland cotton squares of first-generation weevils under field conditions, together with the temperature and humidity records. The average period of development in the infested squares while the squares remained on the growing cotton plants is shown to be 10.9 days. During the time the infested squares were on the ground or after they had dropped off the plant the average period of development is shown to be 11.4 days. The average maximum soil temperature was 103.7° F. Since it has been demonstrated that the boll weevil develops most rapidly under a mean temperature of 84° F., the higher temperatures experienced while the square is on the soil retard the developing process and prolong the developmental period of the weevil. Also high soil temperatures are directly responsible for the death of large numbers of immature weevils. At Madison it was observed that a very high percentage of teneral weevils was killed by the heat before the weevils could make an emergence hole in the square.

TABLE XII.—*Summary of development of first generation boll weevils under field conditions on upland cotton.*

Date of oviposition.	Date squares dropped off.	Date hatched.	Total number weevils bred.		Average period of development.			Mean air humidity.	Mean soil temperature.	Average maximum soil temperature.
			Male.	Female.	On plant.	On ground.	Total.			
					Days.	*Days.*	*Days.*			
May 29-June 1...	June 6-June 25.	June 17-June 25.	8	6	11.6	10.1	21.7	65.5	85.4	111.7
May 29-June 21..	June 7-July 8...	June 12-July 10.	15	7	11.2	10.8	22	72.2	82.3	101.6
May 29-June 5...	June 9-June 16.	June 20-June 25.	7	3	10.8	9.4	21.2	65.2	85.5	109.7
June 1-June 14...	June 11-June 24	June 20-July 5..	8	3	11.2	12.7	23.5	76.3	81	101.6
June 2-June 8...	June 11-June 23	June 22-June 25.	2	0	11	10.5	21.5	62.5	85.5	109.7
June 8-June 15..	June 16-June 30	June 30-July 5..	5	4	10.1	12.2	22.3	76.3	81	101.6
June 9 to June 13.	June 18-June 23	July 2-July 5...	1	3	11.5	11.0	22.5	76.3	81	101.6
June 6-June 14...	June 17-July 1..	July 3-July 9...	7	3	10.3	13.7	24	75.96	81.4	101.3
June 8-June 19...	June 16-June 30	July 1-July 5...	5	4	10.4	13.3	23.7	76.3	81	101.6
June 12-June 21..	June 18-July 4..	July 5-July 10..	6	7	9.3	12	21.3	77.2	82.3	101.6
June 12-June 23..	June 19-July 8..	July 2-July 13..	5	7	12	11.8	23.8	79.2	82.8	101.2
June 18-June 22..	June 30-July 8..	July 11-July 13.	4	5	12.5	9.4	21.9	79.2	82.8	101.2
Total......	....	....	73	52	......	......	......	......	......	......
Weighted average.	....	....	......	......	10.9	11.4	22.4	73.51	82.6	103.7

DEVELOPMENTAL PERIOD OF FIRST GENERATION BOLL WEEVILS ON SHORT STAPLE UPLAND, SEA-ISLAND, AND LONG-STAPLE UPLAND COTTONS UNDER FIELD CONDITIONS.

In addition to the series of hibernated female weevils under observation a series of first generation weevils was used to determine the difference in the length of the developmental period under field conditions on upland, sea-island, and long-staple cottons.

The first generation female weevils deposited eggs at an average rate of 7.6 eggs per day on sea-island cotton. The maximum number of eggs deposited during any one day in sea-island cotton squares was 29.

The 10 female weevils under observation on long-staple cotton squares deposited eggs at an average rate of 6.3 eggs per day. The greatest number of eggs deposited during one day in long-staple squares was 21 eggs.

On upland cotton the 10 female weevils deposited eggs at an average rate of 6.2 eggs per day, with a maximum of 23 eggs deposited by a single female during one day.

On upland cotton the infested squares remained on the plants for an average period of 10.9 days. A period of 11.4 days was the average time required to complete the development of the immature stages after infested squares dropped off the plant.

The average number of days elapsing from the date of egg puncture to the falling of the infested squares was 10.7 on sea-island cotton. The average number of days required to complete the de-

velopment of the immature weevil after the sea-island squares dropped off the plant was 10.4.

The infested squares on the long-staple cotton required 12.3 days from the date of the egg puncture to the falling of the infested square. The time required for the immature weevil stages to complete their development after the long-staple squares dropped off the cotton plants averaged 10.5 days. One of the objections to the long-staple varieties of cotton is the tendency of the infested squares to hang on the plants, protecting the immature weevil stages to a certain extent from natural enemies and mechanical injury.

A total of 92 male weevils of the first generation bred in sea-island cotton squares required 2,006 weevil days or an average period of

FIG. 10.—Shallow wooden troughs filled with crude oil to keep ants out of the weevil hatchery, Madison, Fla.

21.8 days for development of the immature stage. The 75 female weevils bred from the same source required a total of 1,651 weevil days or an average period of 22 days for development from egg to adult. An average period of 21.9 days was required for the development of both sexes of the first-generation weevils in sea-island cotton squares.

The 35 male weevils bred from long-staple cotton squares required a total of 726 weevil days or an average period of 20.7 days from egg to adult. A total of 549 weevil days was required for the development of the 26 female weevils from long-staple cotton squares, or an average of 21.8 days. The developmental period in long-staple cotton squares for both sexes from egg to adult averaged 20.9 days.

A total of 61 male weevils of the first generation bred in upland cotton squares under field conditions required 1,344 weevil days, or an average period of development of 22 days. The 33 female weevils

of the same series required 718 weevil days, or an average developmental period from egg to adult of 21.8 days. The developmental period for both sexes under field conditions averaged 21.1 days from egg to adult.

The total percentage of the infested squares producing adult weevils could not be determined, as a considerable number of the infested squares under observation were detroyed by ants, *Solenopsis* sp. (fig. 10).

COMPARISON OF THE DEVELOPMENTAL PERIOD OF THE IMMATURE STAGES OF THE BOLL WEEVIL UNDER FIELD AND INSECTARY CONDITIONS.

The results of the breeding experiments under outdoor insectary conditions, conducted primarily to check the field breeding records, are tabulated and summarized in Table XIII. The average developmental period under insectary conditions for the hibernated and first-generation weevils in upland cotton squares was 14.5 days. The developmental period of the progeny produced by first generation weevils in long-staple upland and sea-island cottons was 14.2 and 13.7 days, respectively. There is little if any difference in the length of the developmental period of the weevils bred in the three types of cotton squares under insectary conditions. A total of 1,148 weevils which required 16,568 weevil days or an average period of 14.3 days for development under insectary conditions is recorded for the three types of cotton.

The developmental period of the immature stage of the boll weevil under normal field conditions on short-staple upland, long-staple upland, and sea-island cottons is presented in Table XIV. The male weevils bred in upland cotton squares required 21.7 days for development from egg to adult and the females of the same series required a slightly longer period—22.33 days. A total of 323 weevils bred in upland cotton squares under normal field conditions required an average period of 21.9 days for development from the time the egg was deposited to emergence of the adult weevil.

In sea-island cotton squares 92 male weevils required 2,006 weevil days, or an average period of 21.8 days, for development from egg to adult. The 75 female weevils bred from the same source required 1,651 weevil days or an average period of development of 22 days. Both sexes required an average developmental period of 21.9 days from egg to adult.

On long-staple upland cotton 35 male weevils bred in squares under field conditions required 726 weevil days or an average period of 20.7 days for development of the immature stages. The 26 female weevils required 549 weevil days or an average period of 21.8 days for development. Both sexes bred in long-staple upland cotton squares required an average period of development of 20.9 days from egg to adult.

The 551 weevils bred under field conditions from squares of all three types of cotton required a total of 12,012 weevil days or an average period of development of 21.8 days from egg to adult.

The average developmental period of the weevil in all three types of cotton squares under insectary conditions is shown in Table XIII to be 14.3 days from egg to adult. The average developmental period under normal field conditions for weevils bred from all three types of squares is shown to be 21.8 days. Under actual field conditions it is safe to say the boll weevil requires a period of 7.5 days additional time for development, or fully one-half more time than is required under insectary conditions at Madison, Fla.

TABLE XIII.—*Table showing the developmental period of the boll weevil under insectary conditions, 1919.*

Nature of weevils.	Larval food.	Period of oviposition.	Number of males bred.	Male weevil days.	Average period.	Number of females bred.	Female weevil days.	Average period.	Total number of weevils bred.	Total weevil days.	Average period.
					Days			*Days*			*Days*
Hibernated	Upland cotton squares.	June 5–July 25	247	3,692	14.9	123	1,816	14.7	370	5,508	14.8
First generation		July 5–Aug. 19	189	2,765	14.6	117	1,762	14.3	306	4,438	14.5
Total upland cotton.			436	6,457	14.8	240	3,578	14.5	676	9,946	14.7
Long-staple cotton: First generation	Long-staple squares.	July 9–Aug. 2	210	2,953	14.06	154	2,187	14.2	364	5,140	14.1
Sea-island cotton. First generation	Sea-island squares.	July 5–Aug. 9	67	917	13.6	41	565	13.7	108	1,482	13.7
Total all cotton			713	10,327	14.15	435	6,330	14.1	1,148	16,568	14.3

TABLE XIV.—*Showing the total developmental period of the boll weevil under field conditions.*

Nature of weevils.	Larval food.	Period of oviposition.	Males.			Females.			Both sexes.		
			Number of males bred.	Number of male weevil days.	Average period.	Number of females bred.	Female weevil days.	Average period.	Total number bred.	Total weevil days.	Average period both sexes.
Upland cotton:					*Days*			*Days*			*Days*
Hibernated	Cotton sq	May 29–June 13.	73	1,536	20.9	52	1,145	22.01	125	2,681	20.8
Do	do	June 7–June 22.	23	477	20.7	27	607	22.5	50	1,084	21.6
First generation	do	July 3–Aug. 2	61	1,344	22	33	718	21.8	94	2,062	21.9
Second generation	do	July 31–Aug. 22.	23	539	23.4	31	714	23.03	54	1,253	23.2
Total upland cotton.			180	3,896	21.7	143	3,184	22.33	323	7,080	21.9
Sea-island cotton: First generation	Cotton sq	June 26–Aug. 4.	92	2,006	21.8	75	1,651	22	167	3,657	21.9
Long-staple cotton: First generation	do	June 30–July 30.	35	726	20.7	26	549	21.8	61	1,275	20.9
Total all three types of cotton.			307	6,628	21.4	244	5,384	22.06	551	12,012	21.8

DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL IN GREEN COTTON BOLLS.

Owing to the fact that large numbers of adult weevils in the field at the time the bolls are set deposit eggs in the bolls almost as readily as they do in the squares, it is almost impossible to secure noninfested bolls for breeding purposes. Therefore the following method for securing the developmental period of the weevil in cotton bolls for upland, long-staple, and sea-island cotton was followed.

Large, healthy, grown bolls were examined for egg punctures. The number of egg punctures was recorded on a light string tag, together

FIG. 11.—Green cotton bolls bagged in muslin to secure records on the immature stages of the weevil, Madison, Fla.

with the date of examination. The boll was inclosed in a thin muslin bag to prevent further infestation and allowed to remain on the plant under normal field conditions until the adult weevil emerged. All weevils that emerged were counted and the sex determined.

During the month of August 200 weevil-infested bolls were bagged (fig. 11) on each of the three types of cotton. Daily examinations were made of the bagged bolls after a period of 10 days had elapsed.

The upland cotton bolls produced 7 male weevils that required 233 weevil days for development, or an average period of 33.2 days. The 6 female weevils bred from upland cotton bolls required a total of 207 weevil days, or an average period of 34.5 days from egg to adult.

The 200 long-staple or thick-rind cotton bolls produced 8 male weevils that required 250 weevil days from egg to adult, or an average

period of 31.2 days. A total of 298 weevil days was required by the 10 female weevils bred from long-staple cotton bolls, or an average period of 29.8 days from egg to adult. The sea-island cotton bolls produced 30 male weevils that required 953 weevil days from egg to adult, or an average developmental period of 31.7 days. A total of 18 female weevils bred required 623 weevil days, or an average period of 34.6 days for development from egg to adult. (Fig. 12.)

FIG. 12.—Four cavities in which four boll weevils were reared in a sea-island cotton boll, Madison, Fla.

Since the bolls had probably been punctured from 5 to 7 days before they were bagged, it is evident that the developmental period of the boll weevil in green cotton bolls is approximately 35 to 40 days under the most favorable summer temperatures and longer during the fall months. Howe[9] states that the developmental period of the boll weevil in green upland cotton bolls at Tallulah, La., under insectary conditions, was 16.2 days. At Madison, Fla., the developmental period of the boll weevil in green cotton bolls under actual field conditions more than doubles Howe's record.

FECUNDITY OF THE BOLL WEEVIL IN UPLAND AND SEA-ISLAND COTTON BOLLS.

Throughout the season of 1918 attempts were made to secure records of the fecundity of the weevil in green cotton bolls. More than 200 pairs of weevils were under observation at different times during the season. In no case were clear and concise records secured for individual weevils. For some peculiar reason the females did not oviposit freely in the green cotton bolls under insectary conditions.

PREFERENCE SHOWN BY FEMALE WEEVILS FOR OVIPOSITION IN SEA-ISLAND AND UPLAND COTTON FRUIT.

An experiment to determine the preference by the boll weevil for deposition was made by confining six female weevils over upland and sea-island cotton fruit. The female weevils were confined in a large battery jar on moist sand. Fresh squares and bolls of both sea-island and upland cottons were placed in the jar each morning

[9] Howe, R. W. Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley, U. S. Dept. Agr. Bul. 358, p. 28. 1916.

FIG. 1.—SHOWING POSITION OF EGG PUNCTURES ON SEA-ISLAND COTTON.

FIG. 2.—SHOWING POSITION OF EGG PUNCTURES ON UPLAND COTTON.

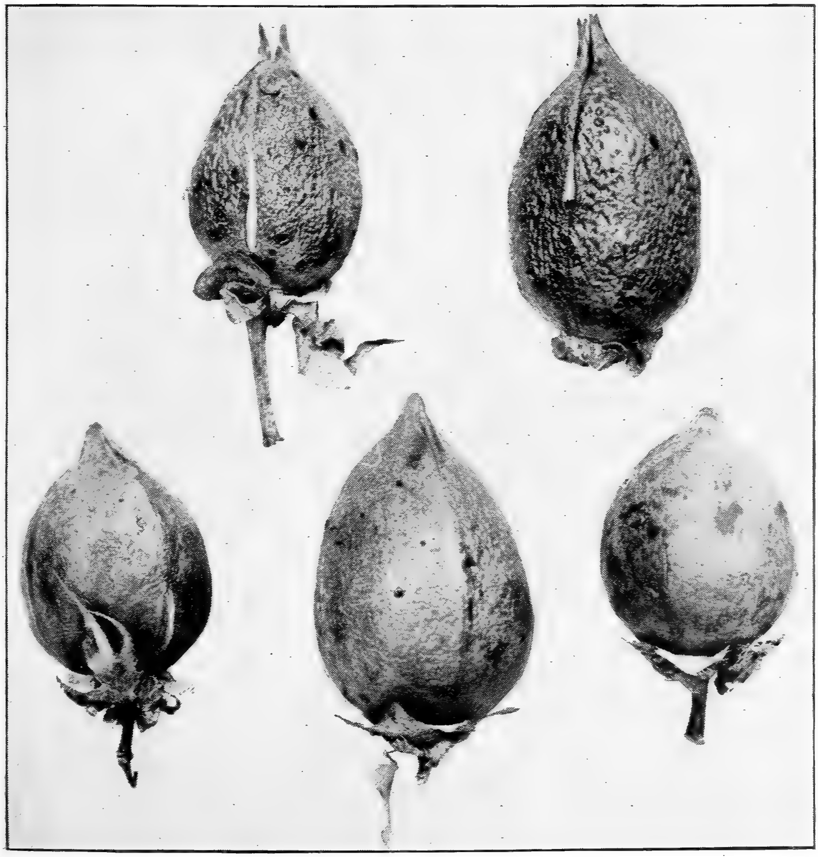

FIG. 3.—THE DIFFERENCE IN STRUCTURE BETWEEN SEA-ISLAND COTTON BOLLS (ABOVE) AND UPLAND COTTON BOLLS (BELOW).

THE BOLL WEEVIL ON SEA-ISLAND AND UPLAND COTTONS.

and all fruit in which eggs had been deposited was recorded and removed from the jar. The records of the experiment are presented in Table XV. A total of 49 eggs were deposited in upland squares compared with 17 eggs deposited in sea-island cotton squares. Eggs were deposited in six sea-island bolls, but in none of the upland cotton bolls.

TABLE XV.—*Preference shown by females of the boll weevil in locations for oviposition on sea-island and upland cotton, Madison, Fla., 1918.*

Date.	Eggs in—			
	Upland squares.	Sea-island squares.	Upland bolls.	Sea-island bolls.
July 17	0	0	0	3
July 18	0	0	0	1
July 19	5	0	0	2
July 20	3	0	0	0
July 21	9	4	0	0
July 22	3	2	0	0
July 23	6	3	0	0
July 24	2	2	0	0
July 25	4	3	0	0
July 26	5	0	0	0
July 27	3	1	0	0
July 29	4	2	0	0
July 31	5	0	0	0
Total	49	17	0	6

COMPARISON OF THE NUMBER OF BOLL WEEVILS THAT EMERGE FROM UPLAND AND SEA-ISLAND SQUARES AND BOLLS.

The writer placed 4,000 upland squares in a large wire-screen cage on August 26, 1918. The squares were carefully examined to determine whether each square was punctured and large enough to support the developing weevil larva. Similarly, 4,000 sea-island squares were put up on the same date.

From the 4,000 upland squares 1,476 adult weevils emerged soon after the squares were placed in the large cage, or a percentage of 36.9. From the sea-island squares 1,979 weevils, or a percentage of 49.4, emerged.

One thousand five hundred upland and 1,500 sea-island bolls were placed in a large wire-screen cage on September 1, 1918, to determine whether more weevils would hatch from sea-island than from upland bolls. It is shown in Plate I that there is a decided difference in structure between the two types of bolls, the sea-island being oblong, with a soft and oily texture. One hundred weevils hatched from the upland bolls compared to 650 weevils from the sea-island-cotton bolls.

From the records secured at Madison, Fla., during 1918, it appeared that the majority of egg punctures in sea-island bolls produced adult boll weevils. It not infrequently happened that as many as from four to eight weevil larvæ would complete their life cycle in a single boll.

THE RELATION OF TEMPERATURE TO THE BIOLOGY OF THE BOLL WEEVIL.

The relationship of temperature to the biology of the weevil has been thoroughly studied for the adult weevil. Little information is available, however, showing the effect of temperature on the immature stages of the weevil. For years the Bureau of Entomology has made so-called status examinations in different parts of the weevil-infested area of the cotton belt to determine the percentage of mortality caused by the heat and dry weather in the immature stages of the weevil. From an examination of 91,082 immature weevil stages Hunter and Pierce [10] found 23.8 per cent killed by heat and dryness. This examination extended over the different months of the growing season from May to October. The relatively small percentage of mortality among the immature weevil stages recorded in this examination is misleading, because the life of the immature weevils was not followed through until the weevil became adult. From the writer's observations at Madison, Fla., the critical period of the immature weevil caused by intense heat seems to extend to the teneral adult stage. Hundreds of teneral adult weevils were observed in squares in the field hatchery that were killed by the heat before they could make an emergence hole in the square. Therefore an examination made to determine the percentage of mortality caused by heat and dryness on any given date is misleading for the simple reason that, although the percentage of immature stages dead may not run very high at the time of examination, yet if it were possible to follow these stages through to emergence of the adult weevil the figures might be trebled. As a concrete illustration, on June 25, 1919, Dr. Pierce examined 451 weevil stages in fallen brown squares taken from plants on which tagged squares were hanging or had fallen. Of the 451 stages examined 134, or a percentage of 38.95, had been killed from climatic causes. At the time this examination was made the writer had 1,378 fallen punctured squares that were tagged on the day of egg-puncture under observation for breeding records. Dr. Pierce's examination indicated that 38.95 per cent of the 1,378 fallen punctured squares would not hatch weevils, since the punctured squares used in his examination were taken from underneath the plants where tagged squares belonging to the writer were lying. However, of the 1,378 squares that were tagged, only 134, or 9.7 per cent, produced adult weevils. It is evident that a field examination is misleading in so far as the percentage of control of the immature weevil stages by heat and dryness is concerned unless these stages can be followed through to the emergence of the adult weevil.

[10] Hunter, W. D., and Pierce, W. D., op. cit.

TEMPERATURES FATAL TO THE IMMATURE STAGES OF THE BOLL WEEVIL

Owing to the lack of proper soil thermometers, it was impossible to determine accurately the fatal temperatures for the immature stages of the weevil. The thermometers in use frequently recorded maximums of 115 to 125° F., and under these maximum soil temperatures it seems safe to assume that not more than 10 per cent of the immature weevils will survive on Norfolk sandy soils such as occur at Madison, Fla.

THE EFFECT OF TEMPERATURE ON THE LENGTH OF THE DEVELOPMENTAL PERIOD OF THE IMMATURE STAGES OF THE BOLL WEEVIL.

Mean temperature and humidity either shorten or prolong the developmental period of the immature weevil. The exact amount of humidity required for development under optimum conditions has never been determined. A mean temperature of 84° F. has been determined as the optimum temperature for development of the immature weevil stages. Were it possible for the immature weevil to have the exact amount of humidity and a mean temperature of 84°, the developmental period of the immature stages would be approximately 8 days. Temperature and humidity, however, are never just in the right proportion and so the period of development varies under different conditions.

THE EFFECT OF TEMPERATURE ON THE LENGTH OF THE DEVELOPMENTAL PERIOD UNDER INSECTARY CONDITIONS.

Under insectary conditions the development of the weevil has been shown to be approximately 14.3 days from egg to adult. This period of development is much shorter than the period under field conditions owing to the smaller variation in extremes of temperature. The mean temperature at Madison, Fla., under insectary conditions during the months of June, July, and August approximates 81° F. according to the United States Weather Bureau records. The average mean temperature is lower by 3° than is required for the optimum developmental conditions. Therefore it is to be expected that the developmental period would be approximately 14 days under insectary conditions.

THE EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF THE IMMATURE STAGES OF THE WEEVIL UNDER FIELD CONDITIONS.

Under field conditions the development of the immature weevil is considerably retarded and prolonged. It has been shown that the infested squares remain on the plants for approximately 11 days after egg puncture. For fully 8 days after egg puncture the sap continues to flow to the injured squares and keeps the temperature lower than is required for proper weevil development. At night the

transpiration of the plant further lowers the temperature surrounding the developing weevil, and for 12 of the 24 hours of the day the minimum temperatures below 84° F. are retarding and prolonging the developmental period. After the infested square drops off the plant it is exposed to the high soil temperatures which range well above 100° F. from 10 a. m. to 5 p. m. The immature weevil is again retarded and all temperatures above 84° F. as well as below 84° F. act as retarding factors.

THE DEVELOPMENTAL PERIOD OF THE BOLL WEEVIL ON DIFFERENT TYPES OF SOIL.

Although the field biology of the boll weevil has not been studied for the different types of soil, the results secured at Madison, Fla., indicate certain generalizations which will probably hold good for the majority of cases.

In addition to heat and dryness soil drainage must be considered. Poorly drained soils such as are found in the Mississippi Delta and the swamps and river bottoms will probably show an average period of development from egg to adult to be a few days shorter than it would be were these soils well drained. On the other hand sandy, well-drained soils, such as the Gulf Coastal Plains, the oak, hickory, and pine uplands, and the rocky hillside types, will probably show a longer period of development than any other generalized type of soil. The semiarid region of Texas should show the longest period of weevil development under field conditions. The range in the developmental period at Madison, Fla., was from 16 to 38 days for weevils developing in squares and it appears probable that the maximum period would be much greater in the dry regions of Texas.

THE EFFECT OF THE DETERMINATE GROWTH OF THE COTTON PLANT ON THE BIOLOGY OF THE BOLL WEEVIL.

Perhaps no single factor contributes so much to the control of the weevil as the determinate growth of the cotton plant. On the Gulf Coastal Plains type of soil at Madison, Fla., the upland cotton usually sets its crop by the 20th of July and the cotton is practically all open by the 20th of August. In addition, the cotton plants are usually attacked by several species of rusts and wilts, which result in the plant becoming decadent, shedding off the leaves, squares, and immature bolls. This leaves the weevil with few breeding places. At this particular time also the weevils are so numerous in the cotton fields that the few squares growing on the plants are subjected to an overwhelming attack for both food and breeding purposes, which results disastrously to the fall generations of the boll weevil. The adult weevils in the field rapidly die off, and as few weevils are

hatching out the number that live to enter hibernation is greatly decreased. The cessation of squaring naturally forces a considerable number of weevils to attack bolls which otherwise might escape. Whether the loss resulting from this attack is offset by an advantage to the crop of the next season on account of the presence of fewer hibernated weevils has not been fully determined.

THE MAXIMUM NUMBER OF GENERATIONS OF THE BOLL WEEVIL UNDER FIELD CONDITIONS.

The number of generations of the boll weevil under field conditions varies with the different seasons and on the different types of soil. A very dry and hot season may affect either generation to such an extent that the eggs deposited during the first half of the generation may not produce weevils at all, and consequently the generation is much prolonged. The following table shows the maximum number of generations at Madison, Fla., under field conditions:

TABLE XVI.—*Maximum number of generations of the boll weevil bred in cotton squares, Madison, Fla.*

Generation.	Date.	Period from maturity to maturity.	Generation.	Date.	Period from maturity to maturity.
First generation:		*Days.*	Fourth generation:		*Days.*
Eggs deposited	June 1		Eggs deposited	Aug. 24	
Generation mature	June 22		Generation mature	Sept. 16	30
Second generation:			Fifth generation:		
Eggs deposited	June 30		Eggs deposited	Sept. 23	
Generation mature	July 20	29	Generation mature	Oct. 16	32
Third generation:			Sixth generation:		
Eggs deposited	July 28		Eggs deposited	Oct. 24	
Generation mature	Aug. 17	29	Generation mature	Nov. 17	33

The average date of killing frost at Madison, Fla., according to the 10-year average of the United States Weather Bureau, is November 29, therefore only six generations of weevils could develop under field conditions.

HIBERNATION OF THE BOLL WEEVIL IN FLORIDA.

During the winter of 1918–19 three series of hibernation experiments were conducted to determine the percentage of weevils surviving the winter at Madison, Fla. The experiments were arranged to secure data on the number of weevils surviving the winter in the open fields and along ditch banks, in the woods on the ground among the leaves and other rubbish, and in the moss covered trees in the woods (figs. 13, 14, 15).

Large wire screen cages 3 by 3 feet by 4 feet high were used for the hibernation experiments. The cages in the fields and on the ground in the woods were filled with an equal amount of moss, leaves, and cornstalks to represent approximately the material the weevils would hibernate in under normal conditions. The cages installed

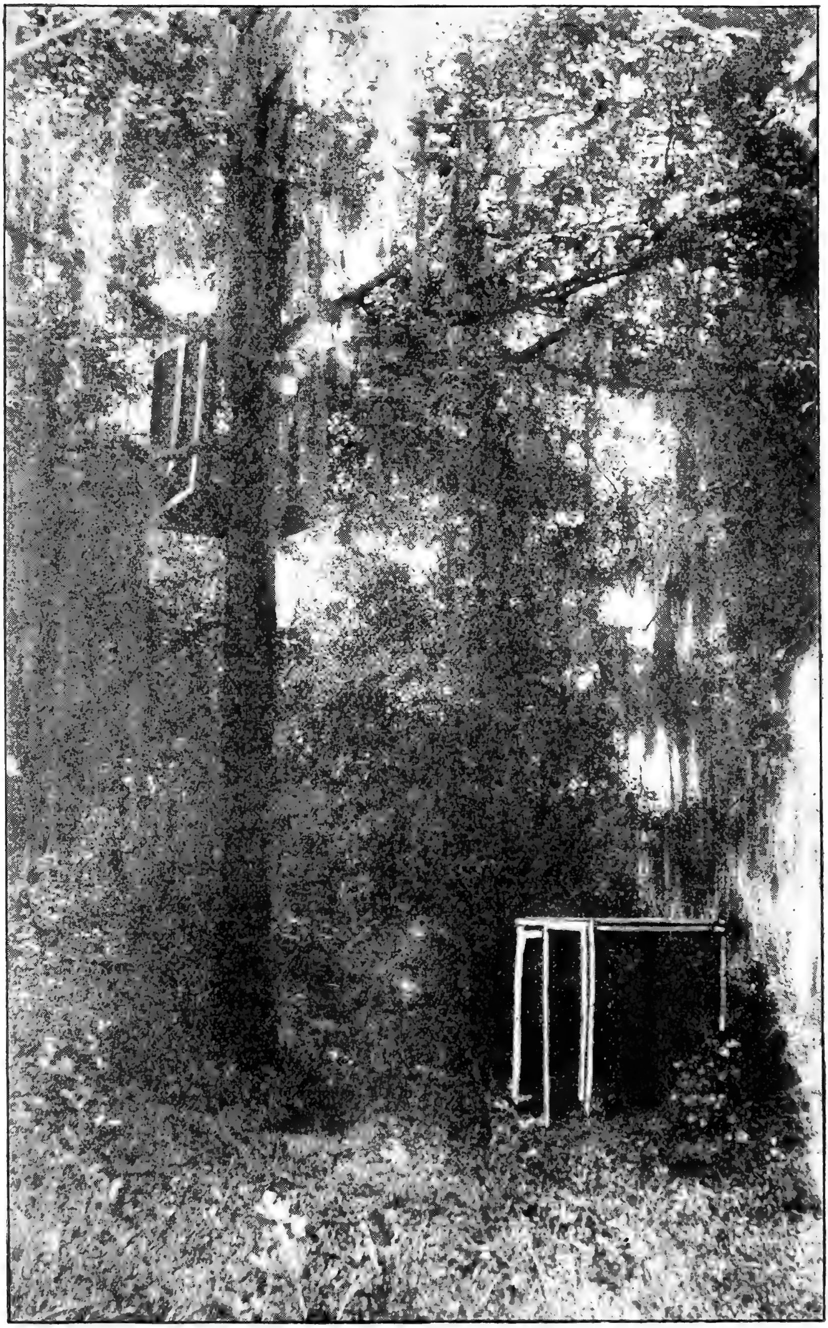

FIG. 13.—Hibernation cages on the ground in the woods, Madison, Fla.

in the trees were supplied with moss only and averaged 10 feet above the surface of the ground (fig. 15).

The boll weevils were collected from near-by cotton fields and installed in the cages every two weeks, beginning on October 1, the last cages being installed on December 1.

TIME OF ENTRANCE INTO HIBERNATION.

The time of entrance into hibernation by the boll weevil at Madison, Fla., usually begins about the time of the first killing frost. The average date of this event is November 29. During the fall of

FIG. 14.—Hibernation cages in the open field at Madison, Fla.

1918, however, the warm weather held on until about December 8. On November 13 the temperature dropped to 37° F., but the 20 days following this drop were extremely warm and all weevils seemed active until the drop in temperature on December 8. The weevils were in hibernation almost continuously until February 20, the date on which the emergence records were started. The mean temperature for November was 59.1° F. and 56.4° F. for December. When it is considered that hibernation begins between mean temperatures of 56 and 60° F. it is seen that the hibernation of the weevil in Florida during November and December is more of a drowsy condition than one of inactivity. The mean temperature for January, 1919, was 46.6° F. and for February 61.9° F. Therefore the weevil really entered hibernation late in December and remained in this condition for the month of January.

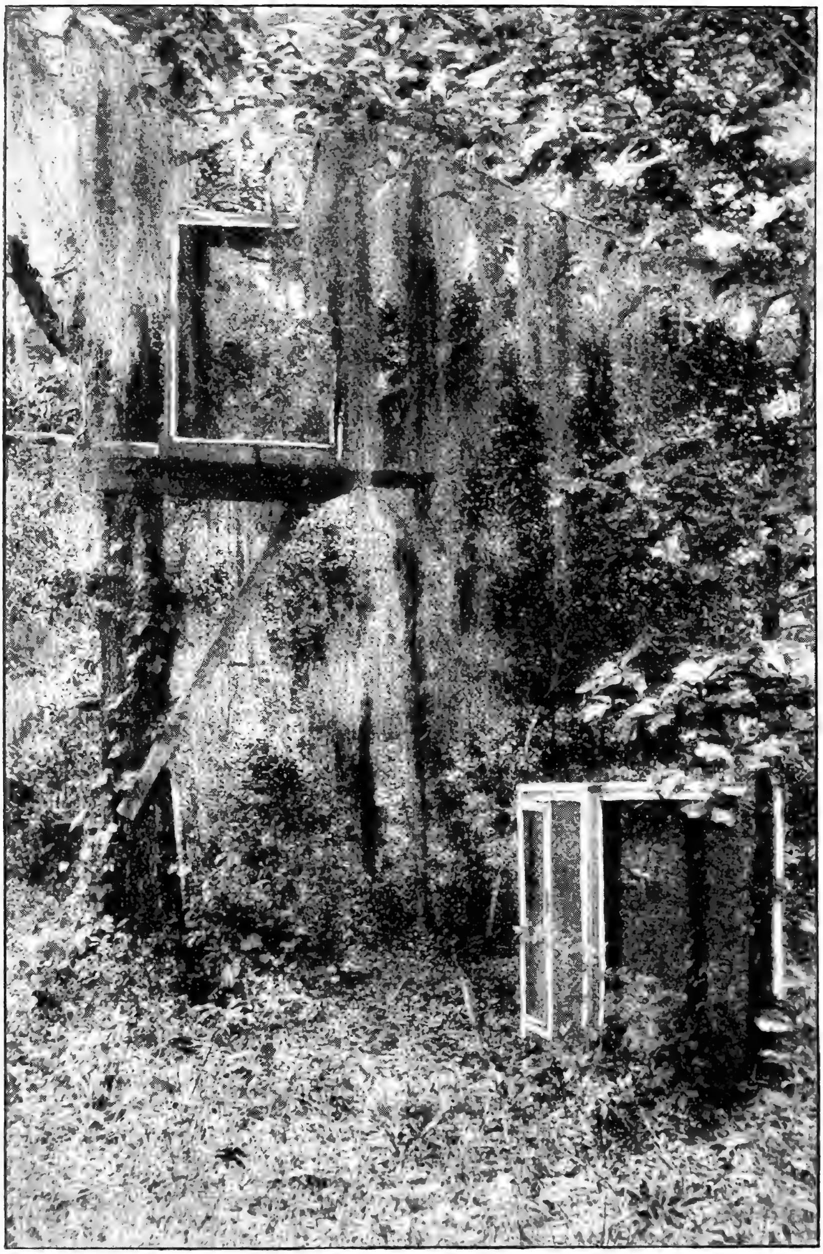

FIG. 15.—Hibernation cages 10 feet above ground in the trees at Madison, Fla.

ACTIVITY DURING THE HIBERNATION PERIOD.

In northern Florida the boll weevil, during the period of hibernation, is seldom inactive for a period of time longer than a month. As was pointed out, the only months in which the average mean temperature is below 56° F. are December and January, and even then it not infrequently happens that warm days occur such as would force the weevil to activity. Thus it might be said that the hibernation of the boll weevil in northern Florida is incomplete.

TIME OF EMERGENCE FROM HIBERNATION.

Owing to the incomplete hibernation of the boll weevil in northern Florida the time of emergence must necessarily be a variable date. February 20 has been selected as the date emergence started in the experimental work at Madison. However, six weevils emerged on the 10th of February and four on the 16th. After February 20 little cold weather is experienced at Madison, and this date may be safely assumed to represent approximately the date when emergence begins for weevils sheltered in places exposed to the direct rays of sunlight.

RATE OF EMERGENCE OF HIBERNATED WEEVILS IN FLORIDA.

The emergence period in Florida extended over the period from February 20 to July 7. The rate of emergence was decidedly more gradual than might be expected when the relatively high temperatures prevailing during March, April, and May are considered. The accompanying diagram (fig. 16) shows the daily rate of emergence of the weevil when hibernating in the open fields, on the ground in the woods, and in the moss on the trees 10 feet above ground. The diagram also shows three prominent periods of emergence, or rather accelerations in the rate of emergence—viz, March 3, April 4, and May 5, 6, and 7. On these dates the rainfall varied from 0.1 of an inch on March 3 to 1.75 inches on May 7. The extreme emergence recorded for May 6, 7, and 8 was also probably influenced by excessive temperatures. In the accompanying chart (fig. 17) the total percentage of rainfall compared to the total percentage of weevils emerged at different dates also indicates that excessive temperature was operating along with the rainfall after the 6th of May.

One of the interesting facts concerning the daily emergence of the weevil when hibernating under the three different conditions is that the emergence from the cages containing moss as hibernation quarters was much later than the emergence from the other two sets of cages. Spanish moss has been proven to be difficult to warm up sufficiently to force the weevils out of winter quarters before late in the season and the results at Madison, Fla., corroborate this fact in every way.

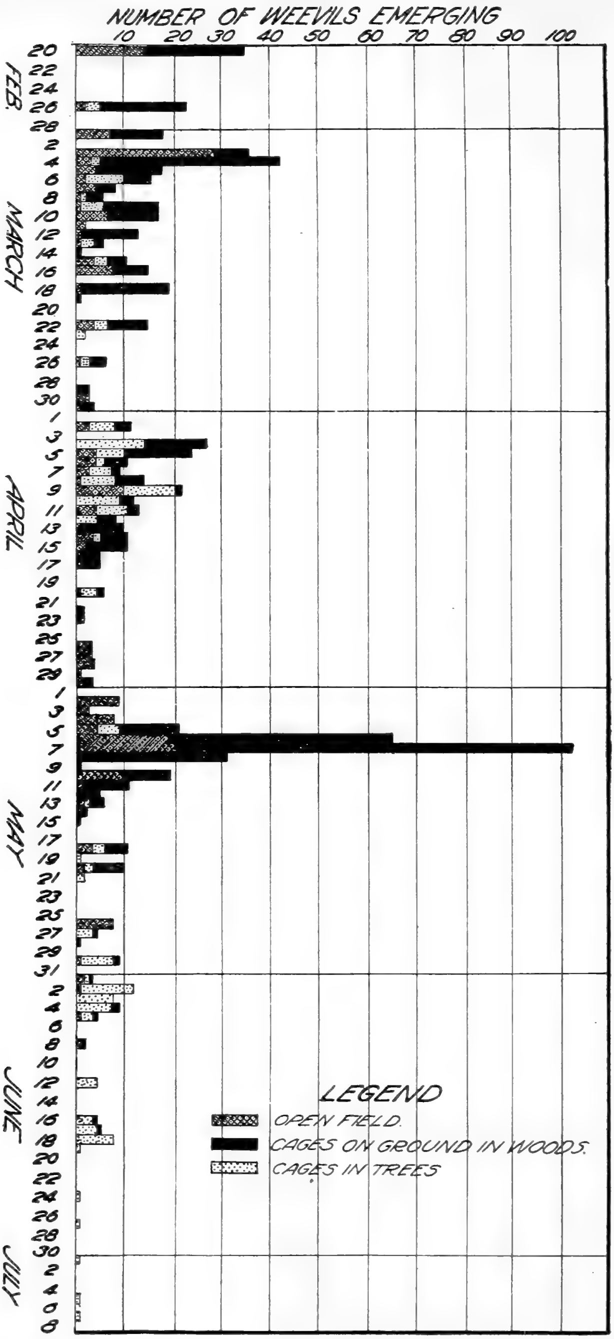

FIG. 16.—Showing the daily rate of emergence of the boll weevil when hibernating in the open field, on the ground in the woods, and in the moss-covered trees, Madison, Fla.

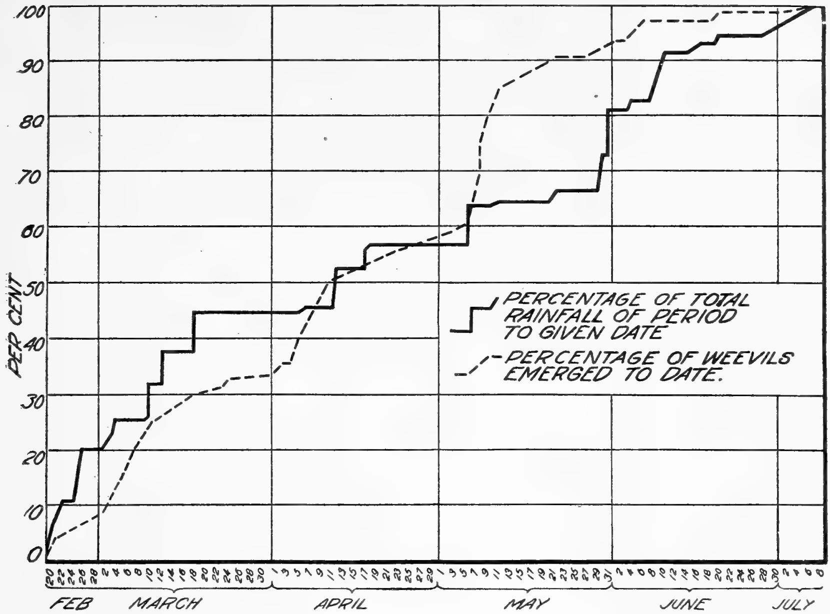

FIG. 17.—Showing the total percentage of rainfall compared with the total percentage of emergence of the boll weevil, Madison, Fla.

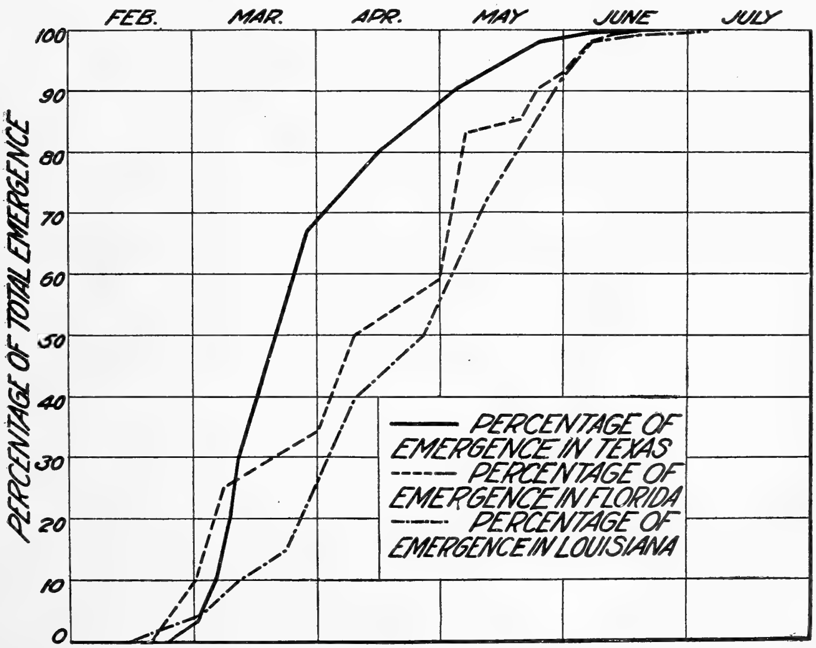

FIG. 18.—Illustrating the rate of emergence from hibernation of the boll weevil in Texas, Louisiana, and Florida.

The rate of emergence in Florida as compared to the rates of emergence in Louisiana and Texas is illustrated in the accompanying diagram (fig. 18). Twenty-five per cent of the boll weevils emerge in Florida a few days before the same percentage emerges in Texas and at least 20 days earlier than in Louisiana. The rate of emergence in Texas shows that 50 per cent of the weevils are out of hibernation approximately 20 days before 50 per cent are out in Florida. After 50 per cent of the weevils emerge the figure shows that the rate of emergence in Florida closely approximates the rate of emergence in Louisiana. This is to be expected since the hibernation shelter in Louisiana and Florida is decidedly more dense than the hibernation shelter found in Texas. Table XVII presents the records showing the percentage of total emergence of the boll weevil at different dates and places where hibernation experiments have been conducted.

TABLE XVII.—*Percentage of total emergence of boll weevils at different dates and at different places.*

Date.	Keatchie, La., 1906.	Tallulah, La.		Mansura, La.		Dallas, Tex.		Calvert, Tex., 1907.	Victoria, Tex., 1907.	Madison, Fla., 1919.
		1910.	1911.	1910.	1909.	1907.	1908.			
Feb. 21	0.00	0.31	36.95	1.64	7.20	0.00	0.00	0.00	0.00	3.6
Feb. 28	.00	.31	36.95	3.28	10.61	.00	.00	.00	12.01	5.03
Mar. 7	.00	6.62	39.92	10.56	19.22	24.48	7.27	22.80	27.92	21.9
Mar. 14	.00	10.09	63.83	15.69	19.73	36.36	23.63	31.90	48.23	30.2
Mar. 21	.00	13.56	70.35	21.19	23.24	57.14	45.45	44.30	66.24	34.2
Mar. 28	3.93	23.34	72.52	38.05	30.96	71.72	55.45	57.20	79.35	36.4
Apr. 4	6.87	35.95	74.69	46.53	38.16	75.70	63.63	64.20	84.16	41.4
Apr. 11	24.54	41.95	81.21	49.42	43.87	81.28	68.18	70.40	89.58	52.3
Apr. 18	32.11	46.05	87.73	52.41	47.78	84.46	74.54	77.40	93.80	57.7
Apr. 25	40.67	48.89	96.42	53.86	56.39	85.74	87.27	79.51	95.02	58.4
May 2	52.73	61.83	96.42	60.41	61.30	88.62	90.91	82.62	95.88	61.2
May 9	60.44	70.66	98.59	72.35	67.51	92.30	91.82	88.73	97.50	85.4
May 16	72.22	75.39	98.59	75.64	75.12	95.75	94.55	91.94	98.36	90.4
May 23	86.41	88.64	98.59	84.77	82.43	98.76	98.18	94.95	98.92	92.5
May 30	91.60	93.69	98.59	92.77	89.73	99.34	98.18	97.56	99.18	94.7
June 6	97.36	99.05	100.00	98.43	96.83	99.78	99.09	99.17	99.90	98.5
June 13	99.19	99.68	100.00	99.89	97.83	99.88	99.09	99.68	99.97	99.1
June 20	99.61	99.68	100.00	100.00	98.74	100.00	100.00	99.99	100.00	99.6
June 27	99.89	100.00	100.00	100.00	99.94	100.00	100.00	100.00	100.00	99.9
July 4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.9
July 7	....	....	....	....	....	....	....	....	....	100.00

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING IN THE OPEN FIELD.

In Table XVIII are presented the data on the number of weevils surviving the winter when installed in the hibernation cages at different dates in the fall under open field conditions. Of a total of 4,300 weevils installed in the cages an average of 5.76 per cent survived the winter. The cage installed on November 15 showed the greatest percentage of the total emergence, while the cage installed on October 1 gave the smallest percentage of emergence. Emergence from hibernation started in all of the cages, except the one installed on December 1, on February 20. As was to be expected the date of

last emergence was made by a weevil placed in the hibernation cage on December 1. The dates on which 25, 50, and 75 per cent of the weevils had emerged follow very closely the sequence of installation.

TABLE XVIII.—*Hibernation of the boll weevil in open field cages, winter 1918–19.*

Cage No.	Date started.	Number of weevils installed.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence	Number emerging.			Percentage of survival.
									Males	Females	Total.	
	1918.		1919.	1919.	1919.	1919.	1919.	*Days.*				
1	Oct. 1	1,000	Feb. 20	Mar. 16	Feb. 20	Feb. 20	Mar. 16	24	1	1	2	0.2
4	Oct. 15	1,000	...do ...	May 27	Mar. 1	Mar. 8	Apr. 2	96	17	21	38	3.8
7	Nov. 1	1,000	...do....	June 2	Mar. 7	Apr. 2	May 6	102	23	22	45	4.5
10	Nov. 15	1,000	...do....	June 1	Mar. 16	Apr. 17	...do ...	101	68	59	127	12.7
13	Dec. 1	300	Mar. 10	June 5	Apr. 11	May 4	May 10	87	14	9	23	7.6
Total		4,300	Feb. 20					410	123	112	235	......
Av.		860						82	24.6	22.4	47	5.76
Max.		1,000						102	68	59	127	12.7
Min.		300						24	1	1	2	.2

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING ON THE GROUND IN THE WOODS.

Woods shelter has always been considered one of the ideal places for successful hibernation of the boll weevil. The results secured at Madison showed a total percentage of survival of 12.8 as compared to 5.76 per cent for the open field. The results of the woods hibernating experiments are presented in Table XIX. In every case the emergence started from the cages on February 20. The cage installed October 1 gave the smallest percentage of emergence (0.8), while the cage installed November 15 gave the highest emergence (20.7 per cent).

TABLE XIX.—*Hibernation records of adult boll weevils in cages on ground in woods.*

Cage No.	Date started.	Number of wevils installed.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence	Number emerging.			Percentage of survival.
									Males	Females	Total.	
	1918.		1919.	1919.	1919.	1919.	1919.	*Days.*				
2	Oct. 1	1,000	Feb. 20	Apr. 2	Feb. 20	Feb. 26	Mar. 4	41	4	4	8	0.8
5	Oct. 15	1,000	.....do..	June 17	Mar. 4	Mar. 16	Apr. 5	117	19	22	41	4.1
8	Nov. 1	1,000	.....do..	June 1	Apr. 4	May 6	May 7	101	115	81	196	19.6
11	Nov. 15	1,000	.....do..	June 8	Mar. 5	Apr. 2	Apr. 28	108	113	94	207	20.7
14	Dec. 1	300	.....do..	June 16	Mar. 12	May 7	May 7	116	30	27	57	19.0
Total		4,300						483	281	228	509	......
Av.		860						96.6	56.2	45.6	101.8	12.8
Max.		1,000						117	115	94	207	20.7
Min.		300						41	4	4	8	0.8

NUMBER OF BOLL WEEVILS SURVIVING THE WINTER WHEN HIBERNATING IN SPANISH MOSS 10 FEET ABOVE GROUND.

The data on the survival of the weevils in cages installed 10 feet above ground in trees are presented in Table XX. Only 4.54 per cent of the 4,400 weevils installed in the cages in the trees survived the winter. The cage installed on November 15, however, gave a total emergence of 10.2 per cent. In connection with the dates of the beginning of emergence of the hibernated weevils it is interesting to note the manner in which the moss held back the weevils, the first emergence not occurring before February 26, and the last emergence taking place on July 7.

TABLE XX.—*Hibernation record of boll weevils in cages installed in the trees.*

Cage No.	Date installed.	Number of weevils in cage.	Date of first emergence.	Date of last emergence.	Date on which 25 per cent had emerged.	Date on which 50 per cent had emerged.	Date on which 75 per cent had emerged.	Period of emergence.	Number emerged. Males.	Females.	Total.	Height above ground.	Per cent of survival.
	1918.		1919.	1919.	1919.	1919.	1919.	Days					
3	Oct. 1	1,000						0	0	0	0	10	0
6	Oct. 15	1,000	Mar. 3	July 1	Apr. 2	Apr. 9	Apr. 14	106	33	27	60	10	6.0
9	Nov. 1	1,000	Mar. 6	July 7	May 10	June 2	June 4	113	20	18	38	10	3.8
12	Nov. 15	1,000	Mar. 4	July 5	Apr. 7	May 5	June 2	112	60	42	102	10	10.2
15	Dec. 1	400	Feb. 26	May 20	Feb. 26	Mar. 8	May 4	83	6	5	11	10	2.7
Total		4,400						414	119	92	211	50	
Av		880						82.8	23.8	18.4	42.2	10	4.54
Max		1,000						113	60	42	102	10	10.2
Min		400						83	0	0	0	10	0

SUMMARY OF THE HIBERNATION OF THE BOLL WEEVIL UNDER ALL CONDITIONS, WINTER 1918–19.

Table XXI gives a summary of the hibernation records secured at Madison, Fla., during the winter 1918–19. The records show that of 13,100 weevils installed in the three sets of hibernation cages at different dates during the fall of 1918, only an average of 7.54 per cent survived the winter. The highest percentage of survival is shown in the cages installed in the woods on the ground. The second highest percentage of survival was in cages installed in the open field and the lowest percentage of survival in the cages installed 10 feet above the ground. It is also noticeable that in every case weevils placed in the hibernation cages on November 15 survived in greater numbers than those placed in the cages at an earlier or later date. It is evident that weevils that become adult right at the time of entrance into hibernation are not in as good physical condition to go through the winter as weevils that have had time to feed longer and thus get their stomach contents in proper condition for entering hibernation. The maximum survival by the weevils that were placed

in the hibernation cages on November 15 was followed in order of total emergence by the survival of weevils placed in the cages November 1 and December 1, respectively.

TABLE XXI.—*Summary of hibernation of Anthonomus grandis under all conditions—winter 1918–19.*

Date started.	Total number of weevils placed in cages.	Open field.			On ground in woods.			In trees in woods.			Total number weevils emerged.		Total percentage surviving winter.
		Number emerged.		Per centage surviving winter.	Number emerged.		Per centage surviving winter.	Number emerged.		Per-centage surviving winter.			
		Males.	Females.		Males.	Females.		Males.	Females		Males.	Females.	
1918.													
Oct. 1...	3,000	1	1	0.2	4	4	0.8	0	0	0	5	5	0.3
Oct. 16..	3,000	17	21	3.8	19	22	4.1	33	27	60	69	70	4.6
Nov. 1...	3,000	23	22	4.5	115	81	19.6	20	18	3.8	158	121	9.3
Nov. 15..	3,000	68	59	12.7	113	94	20.7	60	42	10.2	241	195	14.5
Dec. 1...	1,100	14	9	7.6	30	27	19.0	6	5	2.7	50	41	9.0
Total..	13,100	123	112	....	281	228	....	119	92	....	523	432	....
Av....	....	24.6	22.4	5.76	56.2	45.6	12.8	23.8	18.4	15.34	104.6	86.4	7.54
Max...	....	68	59	12.7	115	94	20.7	60	42	60	241	195	14.5
Min...	....	1	1	0.2	4	4	0.8	6	5	0	5	5	0.3

GENERAL SUMMARY.

At Madison, Fla., the average longevity of hibernated weevils without food was 12.7 days, and 18.8 days when fed on cotton plantlets. Adult weevils of the first and second generations lived 24.3 days on cotton squares and 12.3 days on cotton bolls.

On sea-island cotton plantlets the hibernated weevils lived 11.05 days. The first and second generation weevils fed on sea-island cotton squares lived 10.7 days, while the weevils fed on sea-island cotton bolls lived only 15.3 days.

There is practically no difference in the longevity of boll weevils on sea-island and upland cottons.

The average period from the time the weevils become adult to oviposition at Madison, Fla., for all experiments, was 8.9 days for weevils bred under insectary conditions and 7.07 days for weevils bred under field conditions.

The average period of oviposition under insectary conditions for all weevils under observation on upland cotton was 33.1 days. The entire series deposited eggs over an average period of 31.7 days on sea-island cotton. The largest number of eggs deposited by a single female weevil was 432. This record was made by a hibernated female on upland cotton squares under insectary conditions. The largest number of eggs deposited during any one day under insectary conditions was 25. This record was also made by a hibernated female weevil.

The average period from oviposition to adult of all weevils bred under insectary conditions on upland cotton squares was 14.91 days. On sea-island cotton the average period from egg to adult for all weevils bred under insectary conditions was 14.94 days.

The field-bred weevils showed more vitality than weevils bred under artificial conditions.

Under field conditions the average length of time the infested squares hung on the upland cotton plants after egg puncture was 11.5 days. The time required to complete the development of the immature weevil after the infested square dropped to the ground was 10.8 days in upland cotton squares.

There was practically no difference shown in the length of the developmental period of the boll weevils bred in short-staple upland, long-staple upland, and sea-island cotton squares.

The developmental period of the boll weevil was approximately 7.5 days longer under field conditions than under insectary conditions at Madison, Fla.

Soil temperatures of 120° F. and higher are usually fatal to the immature weevils under field conditions.

The boll weevil at Madison, Fla., shows a decided tendency to form a new variety.

The hibernation of the weevil at Madison, Fla., is incomplete and the adults are seldom inactive more than 30 days at a time.

The emergence from hibernation of the weevil in Florida is very gradual, the total daily emergence bearing a direct relation to the total daily rainfall.

Weevils survived the winter in larger numbers in cages set on the ground in the woods than in the open field or in cages in trees 10 feet above ground. Weevils placed in hibernation cages on November 15 survived in larger numbers than on any other date of installation.

The percentage of total emergence from hibernation begins with more acceleration in Florida than in Texas up to the time that 25 per cent emerges. After 25 per cent of the weevils have emerged in Florida the emergence is less rapid and the Florida emergence curve very closely approaches the emergence curve for Louisiana.

The total percentage of hibernating weevils that survived the winter of 1918–19 at Madison, Fla., was 7.54.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
▽